Current Biology, Vol. 15, 1469–1472, August 23, 2005, ©2005 Elsevier Ltd All rights reserved. DOI 10.1016/j.cub.2005.06.068

Implicitly Evoked Actions Modulate Visual Selection: Evidence from Parietal Extinction

Giuseppe di Pellegrino,[1,*] Robert Rafal,[2] and Steven P. Tipper[2,*]

[1]Department of Psychology
University of Bologna
40127 Bologna
Italy

[2]School of Psychology
University of Wales
Bangor, LL57 2AS
United Kingdom

Summary

It has been proposed that the mental representation of a graspable object involves not only a description of its visual properties but also encodings of the motor programs to act upon it [1]. Thus, observing a handle automatically primes the motor programs responsible for reaching and grasping it. Here, we provide neurological evidence that such action-related object features can bias visual selection. Two patients with visual extinction after right-parietal injury detected cups with left- or right-oriented handles, briefly displayed in either or both visual fields. People with this disorder have deficient awareness for stimuli toward the contralesional, left side of space, especially when competing stimuli appear further to the right [2]. This contralesional extinction was significantly reduced when cups had handles affording a left-hand grasp, even though no hand response was required. No effect was found when handles were replaced with patches equated for position, size, and mean luminance. These data suggest that action-related information may be correctly extracted by the visual system, even though they are unavailable for conscious report. It is proposed that an object affordance for grasping modulates attentional selection by activating specific motor schema that, in turn, enhance the competitive strength of that object representation.

Results and Discussion

Adaptive interactions with the environment require an intimate linkage between vision and action systems. Psychologist James J. Gibson [3] first introduced the notion of affordance, which refers to the property of an object or feature of the immediate environment that directly links perception and motor performance. There is now accumulating evidence, ranging from behavioral [1, 4] to physiological studies [5, 6], that simply viewing an object can partially activate possible actions toward it, even in the absence of explicit intentions to act. Thus, observing a handle automatically primes the motor programs for its reaching and grasping within a perceiver.

*Correspondence: g.dipellegrino@unibo.it (G.d.P.); s.tipper@bangor.ac.uk (S.P.T.)

The opposite is also true. There is evidence that activation of the motor system may affect visual processing [7]. For instance, programming of manual responses triggers covert shifts of attention toward the side of the effector involved in the execution of these responses [8]. Here, our goal was to examine the influence of object affordance on visuo-spatial selection. Particularly, we asked whether, analogous to attentional orienting induced by motor preparation, attention shifts are also triggered by actions automatically activated by visual affordances.

The study focused on two patients with visual extinction after unilateral brain damage (Figure 1). Patients with this disorder may detect a single stimulus in either visual field; however, when two stimuli are presented concurrently, the contralesional stimulus (i.e., the stimulus on the left side of space after right hemisphere damage) is excluded from awareness [2]. Extinction entails an abnormal bias in visual attention in the favor of ipsilesional stimuli, with a failure to direct attention toward the contralesional side of space under competitive conditions [9]. In this framework, we measured the extinction rate (e.g., left detection on double simultaneous stimulation) for objects (e.g., cups) that only varied with respect to the orientation of their affording handles (Figure 2). Because cups were presented to the left and right visual field, any general effects caused by the presence of a graspable cup were counter balanced. Only one of these cups contained a handle (or handle feature). If object affordance enhances visual selection toward the side of the hand most suited to respond to the handle, then we would expect lower rates of left visual extinction for objects with handles evoking a left-handed grasp as opposed to objects with handles eliciting a right-handed grasp.

Detection of right-side (ipsilesional) stimuli was nearly perfect for both patients, regardless of condition of stimulation. In contrast, both subjects detected fewer left-side stimuli in the bilateral than in the unilateral left display (J.P., 56% versus 94%; P.S., 58% versus 94%; $p < 0.05$ in both cases, Student's t test), confirming that they suffered from left visual extinction. Of most importance to our investigation, however, was how action-related object properties influenced the report of left, contralesional stimuli on bilateral displays (see results in Figure 3). To this end, the number of left correct trials were entered into a mixed design ANOVA with Condition (experimental versus control) and Orientation of feature (left versus right side of the cup) treated as a within-subject factor and Patient as a between-subject factor. Each session was entered as a subject nested within the patient factor. Separate ANOVAs were computed for trials in which handle/cue varied in the left (affected) and in the right (intact) visual hemifield. In the left hemifield, there was a main effect of Orientation ($F[1,6] = 34.7$, $p < 0.001$), indicating better left detection when cups had a feature on the left side relative to the right side. More crucially, there was a significant two-way interaction between Condition and Orientation of feature ($F[1,6] = 34$, $p < 0.001$), which reflected the fact

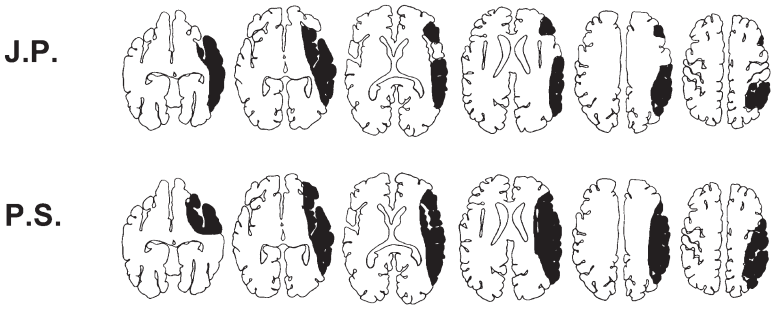

Figure 1. Reconstruction of Patients' Lesions

Brain lesions from CT and MRI scans have been redrawn onto standard slices according to the method of Damasio and Damasio [27]. We tested two patients with damage to right parietal cortex. Patient J.P. was a 81-year-old right-handed woman with a right hemisphere lesion following a right middle cerebral artery infarct. Testing began approximately 18 months after her stroke. A CT scan revealed an area of reduced density that involved the right inferior parietal lobule (Brodmann areas 40 and 39) up to the intraparietal sulcus, superior, and middle temporal gyrus (Brodmann areas 22 and 21); it spared the precentral gyrus and basal ganglia but involved the later aspect of prefrontal cortex. She was living independently, and a neurological examination showed no evidence of motor or somatosensory deficits of the limbs. Likewise, J.P. had intact visual field when tested by Goldman and computerized perimetry. She was fully alert, perfectly oriented to time and place, and willing to collaborate. There was dressing apraxia but no clinical signs of personal and extrapersonal left neglect on several conventional tasks (letter cancellation, line bisection, text and word reading) and no contralesional extinction on auditory and tactile bilateral stimulation. On neuropsychological testing, there was a reliable left-sided visual extinction with brief, unmasked computer displays. Patient P.S. was a 55-year-old right-handed woman who suffered a right middle cerebral artery infarct resulting in a left limb hemiplegia. Magnetic resonance imaging (MRI) revealed infarction in the right middle artery territory, involving the inferior parietal lobule (Brodmann areas 40 and 39), pre- and postrolandic cortex (Brodmann areas 4, 3,1, and 2), the posterior aspect of ventral premotor cortex (Brodmann area 6), and the superior temporal gyrus (Brodmann area 22). Testing began 15 months later, at which time a neurological examination showed a left-hand weakness associated with a partial-position sense deficit. Visual fields were full on both sides, but left visual extinction was reliably obtained on bilateral simultaneous stimulation. No unilateral neglect was apparent on different standardized tests. P.S. was fully alert, oriented to time and place, and collaborative.

that cups with left-side handles produced less left visual extinction than cups with right-side handles (J.P., 81% versus 47% correct; P.S., 78% versus 56% correct; $p < 0.05$ in both cases, t test with Bonferroni correction), whereas no extinction difference emerged for cups with left and right patches. There was no interaction with the Patient factor, indicating that the effect was equal in two patients. Likewise, when cup affordances varied in the right hemifield, there was a main effect of Orientation ($F[1,6] = 14.4$, $p < 0.009$) as well as a significant interaction between Condition and Orientation ($F[1,6] = 3.78$, $p < 0.037$), which replicated the results obtained in the left hemifield.

Previous work has shown that overt/explicit activation of the motor system can feed into brain systems concerned with perceptual processes and thus modulate disorders of visuo-spatial attention. Thus, moving or preparing to move the fingers of the left hand in the left side of space improves detection of targets displayed thereof [10, 11]. Similarly, requiring a patient to search for a target based on the actions most commonly associated with it (e.g., find the object you can

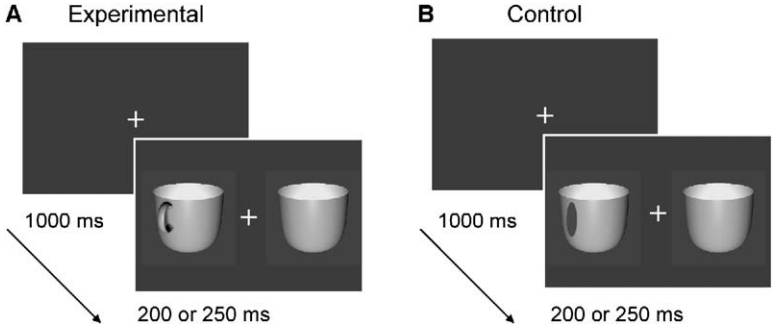

Figure 2. Examples of Double Simultaneous Stimulation from a Block of Experimental Trials and Control Trials, to Scale

The experiments were run on a laptop PC (Dell Latitude) with E-Prime software (PST). Patients sat at a table facing a computer screen (14-inch color monitor with 1024 × 768 spatial resolution) at a distance of ~45 cm. Stimuli were computer-rendered images (Cinema 4D) of 3D grayscale cups, each subtending ~6° × 6° of visual angle, and presented against a dark-gray background. There were three different cup stimuli: (1) cups with their handles oriented toward the left or right side; (2) cups as in (1), except that left and right handles were replaced with visual cues (oval patches of size and mean luminosity equal to the handles) in the same position; and (3) handle-less cups. Note that handles did not protrude out of the cup contour, which was identical for all types of stimuli. Each trial began with patients fixating on a white central cross, as verified by an observer positioned behind the display. After 1 s, either a single cup was briefly presented in the left or right visual hemifield (14° away from fixation) or two cups were shown simultaneously on both sides of fixation. Exposure duration was set such that each patient achieved a performance of roughly 90% correct on single left trials (250 ms for J.P., 200 ms for P.S.). After stimulus presentation, patients were asked to report verbally the location of stimuli (i.e., left, right, or both). Critically, cup visual features (either handles or cues) were completely irrelevant to the patient's task. There were two conditions of interest, administered in separate blocks: Experimental (A) and Control (B) condition. They were identical except that in the Experimental condition, cups with left and right handles were presented, whereas in the Control condition, cups with left and right visual cues were shown. Each condition comprised ten types of equiprobable displays, including six unilateral and four bilateral displays. On unilateral displays, a cup with either a left or right handle (or cue) or a cup without a handle appeared either on the left or right visual hemifield. On bilateral displays, a cup with either a left or right handle (or cue) appeared in the left or right visual hemifield simultaneously with a cup without a handle shown in the opposite hemifield. Each condition was given in four blocks presented in an AB, BA, BA, AB design across four separate testing sessions. Each block consisted out of 80 trials (eight repetitions × ten display types) presented in random order.

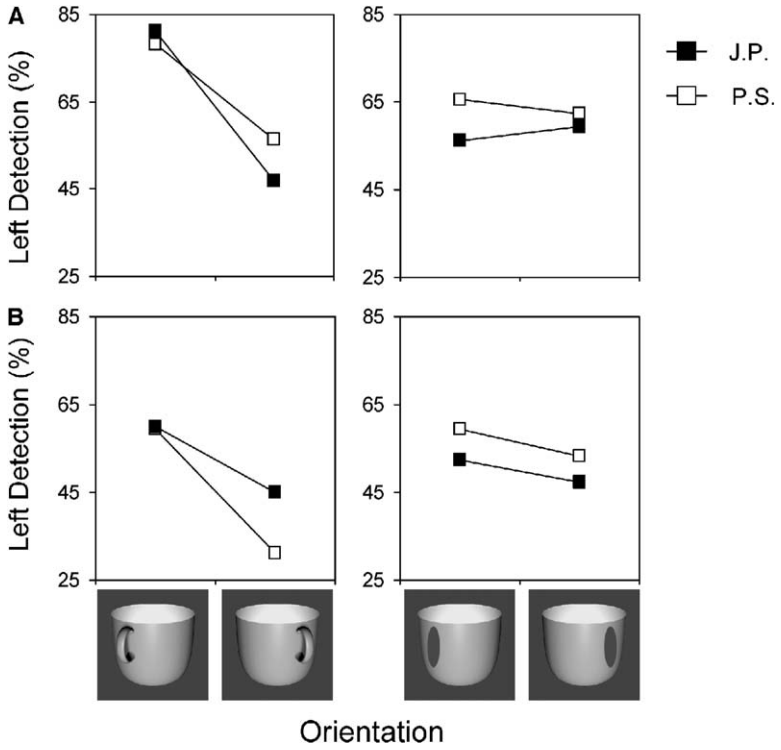

Figure 3. The Effect of Object Affordance on Visual Extinction

Percentage correct detections of left (contralesional) visual targets on double simultaneous stimulation. Data are plotted as a function of cup orientation, in the Experimental (left) and Control condition (right), for patient J.P. (filled squares) and P.S. (empty square). Upper panels (A) depict results when cup orientation varied in the left visual hemifield; lower panels (B) illustrate data when cup orientation varied in the right visual hemifield.

drink from) can also improve detection of stimuli presented toward the impaired region of space [12].

However, several recent studies with normal perceivers show that actions evoked by an object can be automatically encoded, whatever an observer's intention with regards to a seen object might be [1, 4, 13]. For example, when participants are instructed to report the upright or inverted orientation of a graspable object with a left or right-hand response, objects that would be grasped with the right hand (e.g., affording handle is on the right side of object) facilitate such responses when the right-hand, as opposed to the left-hand, response is produced. These effects of action affordances are produced even though they are completely irrelevant to the subject's task, implying automatic computations of action.

Our results demonstrate that action-related object features can bias visual attention and stimulus detection even when object affordances are completely irrelevant to the patient's goals, and no overt hand response is required. Thus, a cup evoking a left-hand grasp facilitates this object's entry into conscious awareness, enabling explicit report of its presence. The finding that oval patches presented in the same location as handles failed to affect visual extinction demonstrates that the observed effect of affordances is not simply due to increased visual cueing by a salient feature [14] or to activation of an abstract, cognitive spatial code (see [1, 4]). Rather, our results reflect the automatic activation of already existing visuomotor schemata linking certain object attributes to specific actions.

How might object affordances modulate patients' visual extinction? According to competitive accounts of visual selection [9, 15, 16], extinction emerges from mechanisms of unbalanced interhemispheric competition. On this view, a unilateral brain damage weakens the competitive weight of contralesional stimuli, thus favoring the selection of ipsilesional ones on double simultaneous presentation. Objects that afford left, contralesional hand actions may specifically enhance motor and motor-related representations in the affected right hemisphere. This, in turn, partly reduces the competitive imbalance against contralesional events and, therefore, ameliorates visual extinction.

Unlike deficits caused by lesion to primary visual cortex, the loss of awareness that can follow damage to parietal cortex does not rely solely on the position of the stimulus in the visual field but also on its perceptual, semantic, and emotional properties [2, 17]. As we have demonstrated here, whether or not a contralesional object will gain access to awareness depends also on its significance for action. This conclusion converges with other recent research in normal individuals and extinction patients in favoring a view of attention as a mechanism that selects information for specific motor purposes, even in the absence of an overt action [18–22].

Moreover, the results of the present study provide some support for the premotor theory of attention proposed by Rizzolatti and colleagues [7, 23]. On this hypothesis, directing attention to an object should result from the preparation of a specific movement to that object. Our results suggest an extension of this theory: that action-related object features can trigger orienting of attention toward their location, even though there is no explicit intention to act upon the object.

Physiological evidence in humans and monkeys indicates that the mere observation of manipulable objects,

irrespective of the subject's intention, elicits the activation of cortical circuits (e.g., parietal and premotor areas) and subcortical centers (e.g., cerebellum and caudate nucleus) specifically involved in the transformation of visual object information into action [5, 6, 24–26]. Our findings clearly indicate that action-related objects can affect visual attention despite extensive damage to the right parietal lobule, implying that this cortical region does not play a necessary role in mediating the reported effect.

Overall, results demonstrate that action-related information influences visuo-spatial attention even when objects are not accessible to conscious awareness because of extensive right-parietal lesion.

Acknowledgments

This work was supported by a Wellcome Programme grant awarded to S.P.T., number 071924/Z/03/Z.

Received: June 14, 2005
Revised: June 29, 2005
Accepted: June 30, 2005
Published: August 23, 2005

References

1. Tucker, M., and Ellis, R. (1998). On the relation between seen objects and components of potential actions. J. Exp. Psychol. Hum. Percept. Perform. *24*, 830–846.
2. Driver, J., and Mattingley, J.B. (1998). Parietal neglect and visual awareness. Nat. Neurosci. *1*, 17–22.
3. Gibson, J.J. (1979). The Ecological Approach to Visual Perception (Boston: Houghton Mifflin).
4. Phillips, J.C., and Ward, R. (2002). S-R correspondence effects of irrelevant visual affordance: time course and specificity of response activation. Vis. Cogn. *9*, 540–548.
5. Grafton, S.T., Fadiga, L., Arbib, M.A., and Rizzolatti, G. (1997). Premotor cortex activation during observation and naming of familiar tools. Neuroimage *6*, 231–236.
6. Grezes, J., and Decety, J. (2002). Does visual perception of object afford action? Evidence from a neuroimaging study. Neuropsychologia *40*, 212–222.
7. Craighero, L., Fadiga, L., Rizzolatti, G., and Umilta, C. (1999). Action for perception: a motor-visual attentional effect. J. Exp. Psychol. Hum. Percept. Perform. *25*, 1673–1692.
8. Eimer, M., Forster, B., Van Velzen, J., and Prabhu, G. (2005). Covert manual response preparation triggers attentional shifts: ERP evidence for the premotor theory of attention. Neuropsychologia *43*, 957–966.
9. di Pellegrino, G., Basso, G., and Frassinetti, F. (1997). Spatial extinction on double asynchronous stimulation. Neuropsychologia *35*, 1215–1223.
10. Robertson, I.H., and North, N. (1992). Spatio-motor cueing in unilateral left neglect: the role of hemispace, hand and motor activation. Neuropsychologia *30*, 553–563.
11. Mattingley, J.B., Robertson, I.H., and Driver, J. (1998). Modulation of covert visual attention by hand movement: evidence from parietal extinction after right-hemisphere damage. Neurocase *4*, 245–253.
12. Humphreys, G.W., and Riddoch, M.J. (2001). Detection by action: neuropsychological evidence for action-defined templates in search. Nat. Neurosci. *4*, 84–88.
13. Tucker, M., and Ellis, R. (2004). Action priming by briefly presented objects. Acta Psychol. (Amst.) *116*, 185–203.
14. Riddoch, M.J., and Humphreys, G.W. (1983). The effect of cueing on unilateral neglect. Neuropsychologia *21*, 589–599.
15. Duncan, J., Humphreys, G., and Ward, R. (1997). Competitive brain activity in visual attention. Curr. Opin. Neurobiol. *7*, 255–261.
16. Fink, G.R., Driver, J., Rorden, C., Baldeweg, T., and Dolan, R.J. (2000). Neural consequences of competing stimuli in both visual hemifields: a physiological basis for visual extinction. Ann. Neurol. *47*, 440–446.
17. Driver, J., and Vuilleumier, P. (2001). Perceptual awareness and its loss in unilateral neglect and extinction. Cognition *79*, 39–88.
18. Allport, D.A. (1987). Selection for action: some behavioral and neuropsychological consideration of attention and action. In Perspective on Perception and Action, H. Heuer and A.F. Sander, eds. (New Jersey: Lawrence Erlbaum Associates), pp. 395–419.
19. Tipper, S.P., Howard, L.A., and Houghton, G. (1998). Action-based mechanisms of attention. Philos. Trans. R. Soc. Lond. B Biol. Sci. *353*, 1385–1393.
20. Riddoch, M.J., Humphreys, G.W., Edwards, S., Baker, T., and Willson, K. (2003). Seeing the action: neuropsychological evidence for action-based effects on object selection. Nat. Neurosci. *6*, 82–89.
21. Rafal, R., Danziger, S., Grossi, G., Machado, L., and Ward, R. (2002). Visual detection is gated by attending for action: evidence from hemispatial neglect. Proc. Natl. Acad. Sci. USA *99*, 16371–16375.
22. Cohen, A., Ivry, R., Rafal, R., and Kohn, C. (1995). Response code activation by stimuli in the neglected visual field. Neuropsychology *9*, 165–173.
23. Rizzolatti, G., Riggio, L., Dascola, I., and Umilta, C. (1987). Reorienting attention across the horizontal and vertical meridians: evidence in favor of a premotor theory of attention. Neuropsychologia *25*, 31–40.
24. Handy, T.C., Grafton, S.T., Shroff, N.M., Ketay, S., and Gazzaniga, M.S. (2003). Graspable objects grab attention when the potential for action is recognized. Nat. Neurosci. *6*, 421–427.
25. Rizzolatti, G., Camarda, R., Fogassi, L., Gentilucci, M., Luppino, G., and Matelli, M. (1988). Functional organization of inferior area 6 in the macaque monkey. II. Area F5 and the control of distal movements. Exp. Brain Res. *71*, 491–507.
26. Murata, A., Gallese, V., Luppino, G., Kaseda, M., and Sakata, H. (2000). Selectivity for the shape, size, and orientation of objects for grasping in neurons of monkey parietal area AIP. J. Neurophysiol. *83*, 2580–2601.
27. Damasio, H., and Damasio, A.R. (1989). Lesion Analysis in Neuropsychology (New York: Oxford University Press).